AIR-RAID SHELTERS

LEAFLET NO. 3

SPLINTER-PROOF SHELTERS FOR PRIVATE HOUSES AND SMALL BUILDINGS

ISSUED BY THE

CEMENT AND CONCRETE ASSOCIATION

52 GROSVENOR GARDENS LONDON, S.W.1

AIR-RAID SHELTERS

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CONTENTS

INTRODUCTION

This leaflet should be read in conjunction with Air-Raid Shelters Leaflet No. 1 (General), which is in the nature of an introduction, and in which various types of air-raid shelters are classified according to the purpose for which they are intended. It will be evident from a perusal of leaflet No. 1 that the most effective form of passive defence against air attack open to the civil population is the avoidance of concentration: in other words, every house should have its own air-raid shelter in which the occupants of the building can congregate in reasonable safety at a moment's notice, instead of rushing out of doors in an endeavour to take cover in such shelters as may be provided by the local authorities for the floating populations of the streets.

The Government has called for a concerted national effort in Air-Raid Precautions, and has stated that the greatest dangers to be met are high-explosive, incendiary, and gas bombs, in that order of importance. It is obvious, therefore, that the most pressing need is for the provision of shelters which will afford protection, not only from gas, but also from what is of even greater importance, the effects of high-explosives—i.e., splinters, blast, and falling masonry. As far as the individual householder is concerned the chances of a direct hit (by which is meant anywhere within 50 ft.) by a heavy high-explosive bomb are insignificant, and in any case protection from direct hits by such bombs is as a general rule impossible except at a very high cost. On the other hand protection from all other risks is a comparatively simple and inexpensive matter, and it is contended that the conception of the universal home splinter-proof shelter, in the provision of which every householder can play his part, is the logical, feasible, and most economical solution to the problem of bringing into being the most important feature of the national A.R.P. effort in the shortest space of time.

Let the question of home shelters be considered from another angle: the average householder takes out a fire insurance policy, not because he believes he will have a fire sooner or later, but because he knows that a fire may occur even in the best regulated of households. In the same way the prudent householder should insure reasonable safety for his dependents by providing such form of shelter as his premises and means permit, not because he believes in the inevitability of air-raids, but because he recognizes that such a risk exists and should be guarded against. And who can deny the inestimable benefit of being able to take cover in the home instead of having to make a dash out of doors, say in the middle of a cold and wet winter's night, to a hypothetical and probably congested public shelter at a distance ?

WHAT TO DO NOW

Every householder should ask himself now "what should I and my dependents do if an air-raid occurred at this moment?" If no precautions have been taken probably the answer will not be very reassuring, and will give rise to the thought "what can I do now so that in an emergency all members of my household will have a reasonably safe place in which to congregate?"

The first thing to do is to rule out the possibility of a direct hit by a high-explosive bomb—unless, of course, you are so fortunate as to have a deep underground cavern or a suitable cave, etc., near your house; otherwise deep underground work, or a thickness of concrete or other material quite beyond the limit of feasibility for any but the wealthy would be involved. The second step is to remember that gas is the least of the dangers, and that it is far more sensible to do your gas-proofing in a place that is safe from falling masonry, splinters and blast than in a room wherein gas-proofing measures may be rendered ineffective by an incendiary bomb, or by the effects of a high-explosive bomb falling near by.

What, then, can be done by householders? Everyone can do something, no matter how humble his abode or slender his means. Even the occupant of a single room, or the flat tenant, if his own place offers no opportunities of improvising a splinter-proof shelter, can take the initiative by consulting with the other occupants of the building with a view to examining what could be done in the basement or on the ground floor for the common benefit. The landlord can then be approached by the tenants jointly and concrete proposals put forward.

POSITION OF SHELTER

In considering how best to provide a home splinter-proof shelter the householder should turn his attention to the basement (if any), the ground floor, or the garden (again, if any). In the following pages there are set forth practical suggestions on how to set about improvising shelters in each of the above three locations. In the cases of basement and ground floor shelters the remarks are intended to apply to improvisation in existing buildings, but it will be obvious that the same principles can, and in fact should, be followed when designing a new house. Architects and their clients will readily appreciate that much subsequent labour and expense will be saved if suitable air-raid shelter accommodation be incorporated in the original plans.

The pockets of the majority are, of course, shallow, and one of the objects of this leaflet is to show how to achieve an effective measure of protection at minimum cost. But the unavoidable expense entailed in providing a home shelter, whether it be a matter of a few pounds or many, will not appear so heavy a burden if the shelter is designed to serve some useful purpose in normal times. All householders who set out to provide themselves with home shelters should give at least as much attention to designing for the peace time use as for the war time function of their shelters.

SIZE OF SHELTER

Before considering where the shelter is to be located the minimum space required for the number of persons to be accommodated should be decided, and this depends on what steps are to be taken to meet the gas risk. The shelter may be (1) ventilated, in which case it may be occupied for an indefinite period, or (2) unventilated. In the first case the exclusion of gas may be accomplished by installing a mechanical ventilation and gas-filtration plant, or by admitting the air through ducting or a chimney, the inlet of which is at least 30 ft. above ground level, where the air should be reasonably free of gas: the vulnerability of the ducting is, perhaps, a disadvantage of this system, though a gas-filter and a fan can be fitted in addition at the shelter end of the air inlet.

The unventilated shelter is used as a sealed chamber, and from the gas point of view is the same thing as a refuge room gas-proofed in accordance with the Home Office A.R.P. Department's recommendations to householders, except that it also affords protection from the greater dangers of splinters, blast, falling masonry and fire. For small home shelters the unventilated type is adequate for a limited period of occupation (see Table No. I overleaf). Inexpensive regeneration units are obtainable which will generate oxygen and absorb the carbon dioxide, thereby extending the safe period of occupation. The limiting factor in unventilated shelters, however, is not so much the using up of the oxygen supply as the gradual rise in temperature and the increase in the humidity of the air due to the presence of the occupants. The higher the temperature the more moisture the air will hold: consequently, in the absence of ventilation, it is essential to make the air give up excess moisture by inducing condensation on the inside surface of the shelter, and the extent to which this will occur depends on the temperature of the walls, floor, and ceiling. The latter should be smooth, dense and inherently cold, characteristics which are readily obtainable by constructing the shelter of concrete.

The householder who is compelled to limit his expenditure on providing a home shelter to the absolute minimum can, of course, decide to rely entirely on gas masks for protection from gas should the need arise, in which case his shelter can be open, and ventilated by natural means.

The following Table shows at a glance how to arrive at the space required for a home splinter-proof shelter, according to whether the shelter is to be ventilated or is to be used as a closed unventilated chamber.

TABLE NO. 1

TYPE OF SHELTER	SPACE REQUIRED PER PERSON
VENTILATED Example: For 5 persons at $7\frac{1}{2}$ sq. ft. floor space each = a room 6 ft. 4 in. $\times$ 6 ft., or 9 ft. 6 in. $\times$ 4 ft.	Minimum for standing room only, $3\frac{1}{2}$ sq. ft. of floor per person. Desirable space for reasonable comfort and to permit lying down, $7\frac{1}{2}$ to 10 sq. ft. per person.
UNVENTILATED Example: For 5 persons at 75 sq. ft. surface area each = a room 10 ft. $\times$ 6 ft. $\times$ 8 ft. high (for 6 hours occupation).	75 sq. ft. of surface area (floor, ceiling and walls) per person, for maximum period of occupation of 6 hours. For 12 hours occupation allow 100 sq. ft. surface area per person.

Having decided whether the shelter is to be ventilated or unventilated, and thus arrived at the space required, the next thing to do is to make a careful examination of the premises, and to decide on location of the shelter, bearing in mind that it must be safe from splinters, blast, falling masonry and fire. Tables Nos. 2 and 3 (see Page 7) should be studied before making this decision.

PROTECTION FROM SPLINTERS, ETC

To resist blast, and the penetration of splinters from high-explosive bombs exploding more than 50 ft. away, the following thicknesses are among those recommended by the Home Office in A.R.P. Handbook No. 6 (*obtainable from H.M. Stationery Office, price 6d.*) :—

TABLE NO. 2

Earth or Sand	30 in.
Unreinforced concrete (not weaker than 1 : 6)	15 in.
Stock bricks in cement mortar	$13\frac{1}{2}$ in.
Reinforced concrete (normal)	12 in.
Reinforced concrete (special)	10 in.
Mild steel plate	$1\frac{1}{2}$ in.

Reinforced concrete 5 in. thick may be expected to keep out incendiary bombs of 2 lb. weight.

STRENGTH OF SHELTER ROOF

The roof of a shelter in, under, or adjoining a building must be strong enough not to collapse if the building above should fall upon it. At the time of writing official recommendations for the strength of shelter roofs to withstand falling masonry have not been published, but it is suggested that a good rule is to design for load of 4 cwt. per sq. ft. in addition to the normal design loading, irrespective of the type of building or number of stories. The main thing to note about Table No. 3 is that for each foot of width of the shelter allow 1 in. of thickness of reinforced concrete in the roof, with the proviso that no roof should be less than 6 in. thick. Thus, if you have a cellar 7 ft. wide, the ceiling will probably be strong enough without further strengthening if it is made of reinforced concrete not less than 7 in. thick. In Table No. 3, which is published by permission of Mr. L. Scott White, M.Inst.C.E., M.I.Struct.E., similar reinforcement is provided in both directions for the purpose of distributing the effects of heavy local loads due to falling masonry, etc.

TABLE NO. 3

ROOF SLABS FOR "SPLINTER-PROOF" AIR-RAID SHELTERS WITHIN BUILDINGS

Designing load: 550 lb. per sq. ft. in addition to weight of slab.
Max. compression in concrete: 750 lb. per sq. in.
Max. tension in reinforcement: 18,000 lb. per sq. in.
Proportions of concrete of ordinary grade: 1 : $2\frac{1}{2}$: 4.
Modular Ratio: 15.

Slabs, free-ended. Bending Moment $B = \frac{WL}{8}$

Span	Thickness	Reinforcement	Notes
4 ft.	6 in.	$\frac{3}{8}$ in. Dia.	(1) Reinforcement to be placed in the bottom of the slab, with 1 in. cover, and to be spaced at 6 in. centres in both directions, forming a grid.
5 ft.	6 in.	$\frac{1}{2}$ in.	
6 ft.	6 in.	$\frac{5}{8}$ in.	
7 ft.	7 in.	$\frac{5}{8}$ in.	
8 ft.	8 in.	$\frac{5}{8}$ in.	
10 ft.	10 in.	$\frac{3}{4}$ in.	
12 ft.	12 in.	$\frac{7}{8}$ in.	(2) A minimum of 1 in. thickness of concrete is required per foot of span.
14 ft.	14 in.	$\frac{7}{8}$ in.	
16 ft.	16 in.	1 in.	
18 ft.	18 in.	1 in.	
20 ft.	20 in.	$1\frac{1}{8}$ in.	*(L. SCOTT WHITE)*

BASEMENT SHELTERS*

Below ground level is obviously the best place for a splinter-proof shelter because of the lateral protection thus secured. If in addition the shelter is located beneath the building it will derive the extra overhead protection from falling splinters, debris, etc., given by the roof and floors of the building above. Consequently, if you have a cellar or basement, consider carefully the

★ *See also the leaflet "Air-Raid Shelters in the Home," which deals with basement shelters designed for dual use as children's playroom, etc., for incorporation in the plans of new buildings.*

The recognition of the possibility of air-raids indicates the desirability of including a dual purpose basement in the design of new houses. Such basement shelters may be suitably planned and decorated to form useful accommodation in normal times.

requirements shown in Tables Nos. 1, 2, and 3, and see whether your home shelter could be prepared therein. The probability is that it could, and that the expense involved would be small : moreover, a shelter in the basement has the advantage of being accessible without going out of doors (a point likely to be much appreciated in inclement weather).

● GENERAL ARRANGEMENT

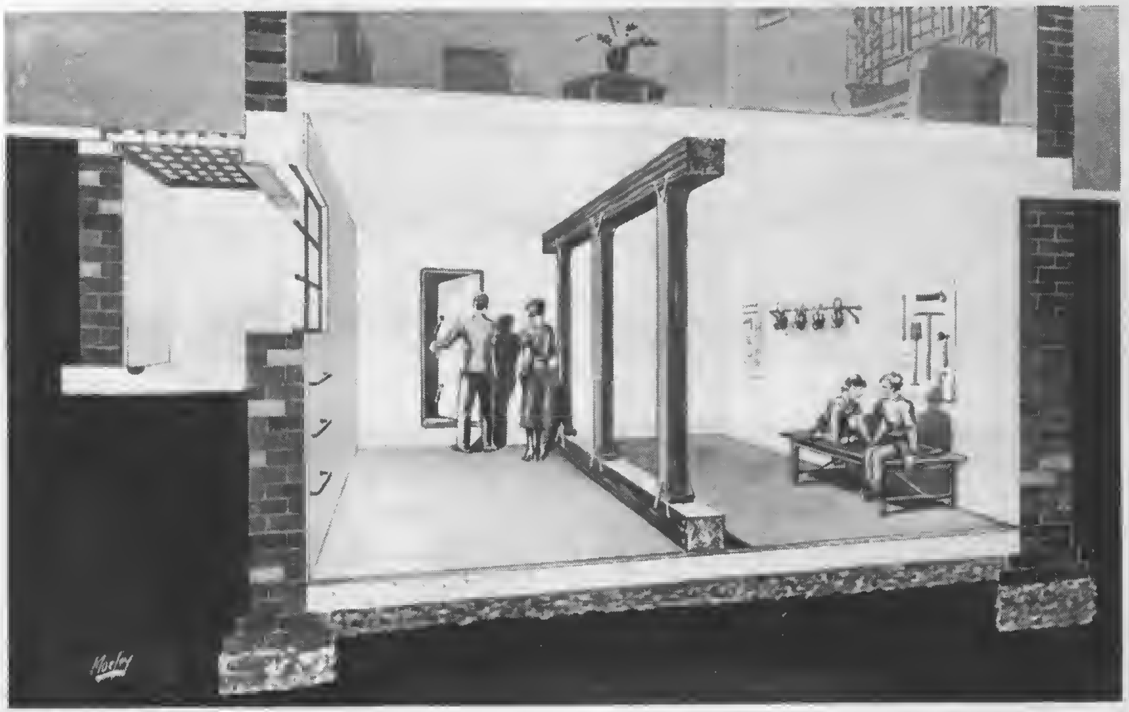
For small home splinter-proof shelters a single chamber will suffice, but if the space is available the following accommodation is desirable in addition : a gas-lock in the entrance, which in the case of a basement shelter may be conveniently formed by doors at the top and bottom of the access staircase : a small toilet room partitioned off in the main shelter, containing a chemical closet ; an emergency exit (see below).

If there is any choice, a basement shelter should be under the centre of the building rather than against the outer walls, and it should not be located near boiler rooms or similar places which might in themselves constitute a risk. Similarly, positions below large water tanks, heavy machinery, etc., which might be dislodged and crash on to the roof of the shelter, are undesirable. Central corridors are obviously advantageous as

the smaller the span of the ceiling the greater its strength, or the less the work involved in increasing its strength. If, as is often the case, a basement is only a basement with reference to street level, all outside walling projecting above ground level should be splinter-proof, e.g.: mass concrete 15 in. thick, or reinforced concrete 12 in. thick. Another factor is the amount of walling that may have to be constructed to enclose the required space, and to form gas-locks, lavatory accommodation, etc. Emergency exits are highly desirable, and should be designed to ensure as far as possible against the risk of blockage by debris: reinforced concrete underground passages leading to the surface well clear of buildings suggest themselves. Daylight is often admitted to basements under city buildings through an outside shaft and glazing in the pavement, special gas-and-splinter-proof fittings are on the market for such pavement lights, and are designed to serve as emergency exits from basement shelters.

● ROOF

If the original detail plans of the building are available the strength of the basement roof can be ascertained: if not, an idea of the strength should be obtained by conducting a thorough



If an existing basement concrete ceiling is not strong enough (see Table No. 3) it may be possible to strengthen it by reducing the unsupported span, but expert advice should be obtained.
Special fittings are obtainable for gas-proof emergency exists via lighting shafts.

examination and by taking measurements. In deciding on the best way of strengthening a roof, if columns and bearers can be placed under the existing roof or ceiling to reduce the unsupported span, it may be remarked that by halving the span roughly 4 times the load can be carried. The reliability of the column foundations is important: the work should be entrusted to capable hands.

If the flooring above can be taken up, a plank and plaster ceiling carried on joists can be strengthened conveniently by filling in with reinforced concrete between the joists, possibly adding a main girder below to reduce the span of the joists. Alternatively, the old ceiling can be replaced entirely in reinforced concrete designed to give the required strength, in which case concrete columns with splayed reinforced capitals and footings can be incorporated as part of the design. Each case should be considered on its merits and expert advice obtained before the work is undertaken.

● WALLS

As regards the outside walls of basement shelters, these should be capable of taking all horizontal forces even when the load on them is reduced by the collapse of the walls above them: the strength of external walls will be much increased by all beams, etc., spanning between them, provided there is rigid connexion between roof and walls. Apart from this, the walls should be of sufficient strength to support safely the shelter roof plus its maximum emergency load. For outside walls of basement shelters 12 in. of reinforced concrete, or the equivalent, should be regarded as the minimum. If a portion of a basement is to be enclosed to form a shelter the walls may be required to assist in the strengthening of the ceiling by bearing part of the load, in which case the remarks concerning columns given above apply. For internal walls 12 in. of plain concrete or 6 in. of reinforced concrete would normally be suitable.

● FLOORS

The ability of the ground under the foundations to take the extra superload should not be overlooked. In basement shelters a concrete floor is in any case desirable for exclusion of water: a reinforced concrete floor not only adds strength by tying the walls together, but also gives better distribution of the load on the foundations. It is recommended that in the design of concrete basement shelters to be incorporated in the plans for new buildings the floor should be not less than half the thickness of the shelter ceiling (with a minimum of 6 in.), and with reinforcement, placed 2 in. from the upper surface, appropriate to the thickness as shown in Table No. 3.

● WATERTIGHTNESS, ETC.

Other points to be considered in adapting a basement to serve as an air-raid shelter include watertightness—the levels of existing drains, etc., should be investigated—and what will have to be done in connexion with the selected method of gas-proofing. In sealing up crevices, etc., pipes, conduits and so forth which may be present

should not be overlooked. If mechanical ventilation is to be installed in conjunction with a gas-filtration plant, so long as the plant is capable of maintaining a plenum in the shelter, porosity of the walls and ceiling is of no great moment. If the shelter is to be used as a closed unventilated space and it is considered desirable to reduce porosity, it is logical to treat the outside, rather than the inside surfaces, where possible. In the case of new construction a layer of bitumen or other non-porous substance may be sandwiched between two 6 in. thicknesses of concrete walling.

● SUMMARY

From a perusal of the above it will be seen that, when examining an existing basement or cellar to see whether it can be easily adapted to serve as a home splinter-proof shelter, the important points are: Is it large enough? Is the ceiling strong enough and, if not, could it be strengthened easily? Remember that the narrower the width of a basement, the stronger the ceiling—or the easier it is to strengthen it. What about the walls and floor? Probably nothing need be done to these, especially if the basement is wholly below ground level, and the floor is reasonably dry. If there is a light shaft leading to ground level it can be adapted to serve as an emergency exit. The installation of an electric light point, if none exists, is desirable.

GROUND FLOOR SHELTERS

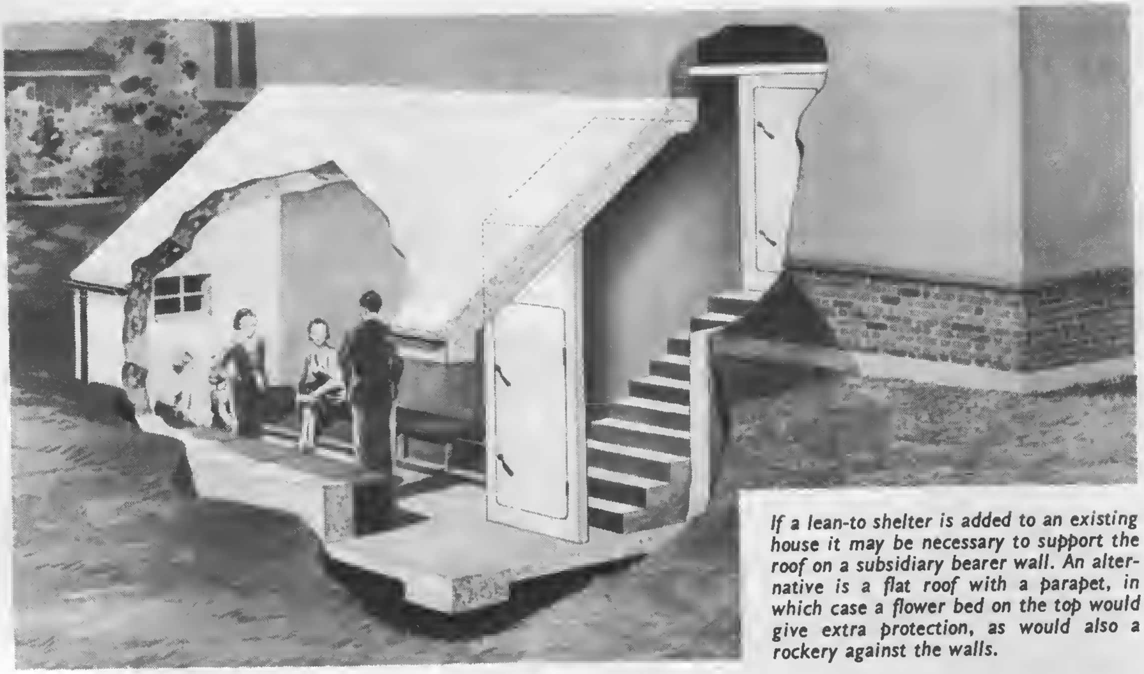
For cases where neither basement nor outside shelters are possible,the most suitable room on, or section of, the ground floor may be adapted in a similar manner to that described for basements, but with the additional attention necessary to render the walls splinter-proof if they are not already thick enough (see Table No. 2), and to protect doors and windows. The latter may be permanently closed with the necessary thickness of concrete, or traverses may be constructed outside in accordance with the directions given in A.R.P. Handbook No. 6.

In planning new houses such spaces as the scullery, or larder, etc., can be designed for dual use as a splinter-proof shelter at very slight extra cost. The only special structural requirements are splinter-proof outside walls—say unreinforced concrete 15 in. thick, and a reinforced concrete slab ceiling (see Table No. 3). Walls facing the inside of the house need not be so thick, as they are partially protected from splinters by the rest of the building. The entrance should be from the kitchen, etc., or adjoining passage, and if double doors can be arranged with an intervening space

In designs for new houses an alternative to a basement shelter is one on the ground floor, planned for a dual purpose. A small room such as the scullery or larder, etc., can be constructed of reinforced concrete at small additional cost.

this will form a gas-lock. The doors should be of stout construction, say of timber, 2 in. thick, and if they close against a low cill gas-proofing will be easier to make effective. A small window in an outside wall for light and ventilation can be provided with a simple gas-proof form of detachable shutter which in an emergency can be fixed over the opening on the inside with thumb screws. It is preferable that the window should face another building or wall, so as to be masked from flying splinters, etc. In war time the window opening could be further protected by the construction of a sandbag traverse 30 in. thick on the outside, or it could be temporarily bricked up.

Another example of dual purpose design is the built-in strong room air-raid shelter. In existing houses it may sometimes be convenient to form an effective ground floor shelter by constructing a splinter-proof concrete shell within a suitable small room independent of the main structure. If such a room can be spared this expedient has its attractions, for besides being comparatively simple to carry out, a useful fireproof strong room or store is thereby provided for normal use.



If a lean-to shelter is added to an existing house it may be necessary to support the roof on a subsidiary bearer wall. An alternative is a flat roof with a parapet, in which case a flower bed on the top would give extra protection, as would also a rockery against the walls.

LEAN-TO SHELTERS

The illustration exemplifies this type of shelter, and little explanation is required. The walls should be splinter-proof—see Table No. 2—and the roof should be in accordance with Table No. 3. In order to obtain a purchase for the roof against the side of an existing house either corbelling out is required, or a subsidiary bearer wall may be erected against the outside of the existing wall. Entrance direct from the house, as shown in the illustration, is desirable, but is not, of course, essential. Lean-to shelters of this nature may be constructed conveniently in areas such as are frequently to be found outside urban dwellings.

PROPRIETARY DESIGNS

There is a number of firms who specialize in the design and construction of efficient air-raid shelters, ranging from the massive underground type to the splinter-proof shelter-cum-garage dual purpose structures, and those who so desire are in a position to select from the various designs

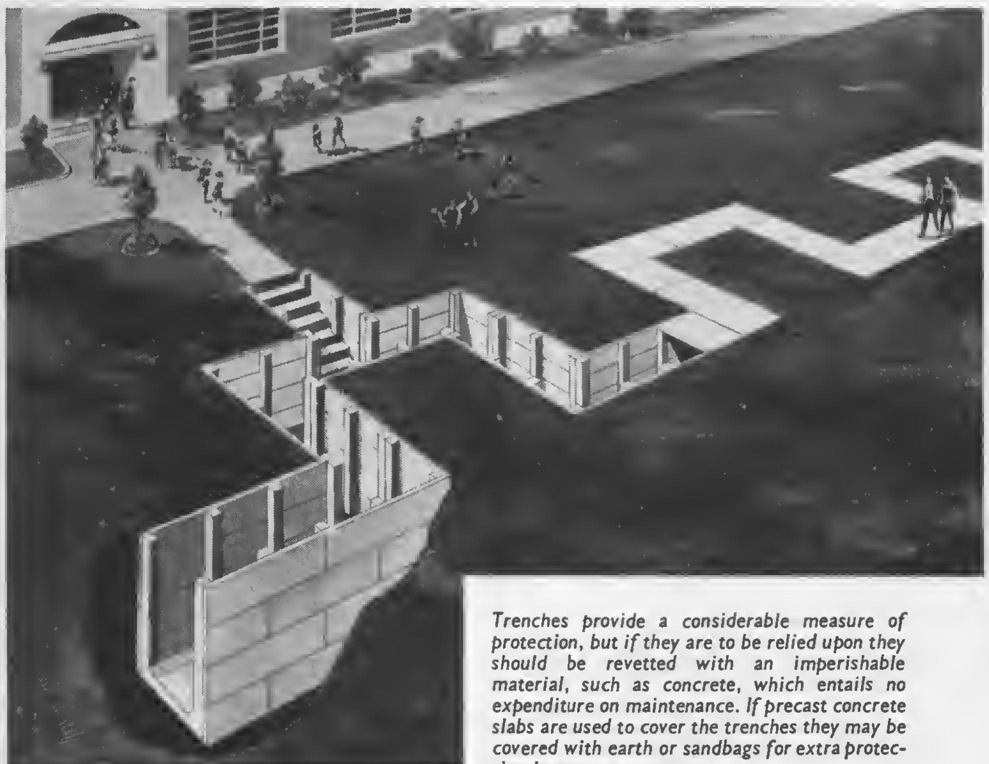
to suit their own particular site and requirements. Houses on sites rising steeply from the road sometimes have an underground garage beneath the front garden, with the entrance at road level: very little adaptation is required to make such a garage suitable for use as a splinter-proof shelter.

SPLINTER-PROOF SHELTERS IN THE OPEN

Military tactics in the face of a bombardment are to scatter and to go to earth: in other words, to take cover in trenches. In the course of time, if the trenches remain in occupation, underground dugouts are constructed for additional protection.

● TRENCHES

Similar tactics are applicable to passive resistance to attack from the air, and where open spaces well clear of buildings are available on the property a considerable measure of protection may be provided by a system of trenches. Full instructions for the design and construction of trenches are given in the Home Office's A.R.P. Handbook No. 6, so details need not be entered into in this leaflet. It should be remembered,



Trenches provide a considerable measure of protection, but if they are to be relied upon they should be revetted with an imperishable material, such as concrete, which entails no expenditure on maintenance. If precast concrete slabs are used to cover the trenches they may be covered with earth or sandbags for extra protection in an emergency.

however, that if reliance is to be placed in trenches they should be constructed in such a manner that they will be permanent. For this purpose "A" frames and revetting material should be of concrete, which will not deteriorate with the passage of time.

Trenches may be provided with overhead cover to give protection from falling bomb splinters, fragments of anti-aircraft shells and debris, in which case they become a form of dugout or splinter-proof shelter. If precast concrete slabs are used for the overhead cover, resting on the top of concrete revetment, and recessed so as to be flush with the surface of the ground, the trench system may be laid out as a formal zig-zag path. Another means of obviating unsightliness in the garden is to construct the trench in concrete and fill it with water, so designing it that it forms an ornamental fish or lily pond in normal times.

● GARDEN SHELTERS

The design and construction of splinter-proof shelters in the open is clearly a much simpler problem than that involved in the design of shelters under buildings, as the main structural requirement is merely the incorporation of a sufficient thickness of material to prevent penetration by splinters, etc., as shown in Table No. 2. Bearing in mind the questions of accessibility, capacity and gas-proofing, the problem resolves itself into what shape and form of construction is the most suitable to the site, and is possible with the money available, and further, to design the shelter so that in normal times it may be put to the best use, e.g., tool sheds, fruit stores,* etc.

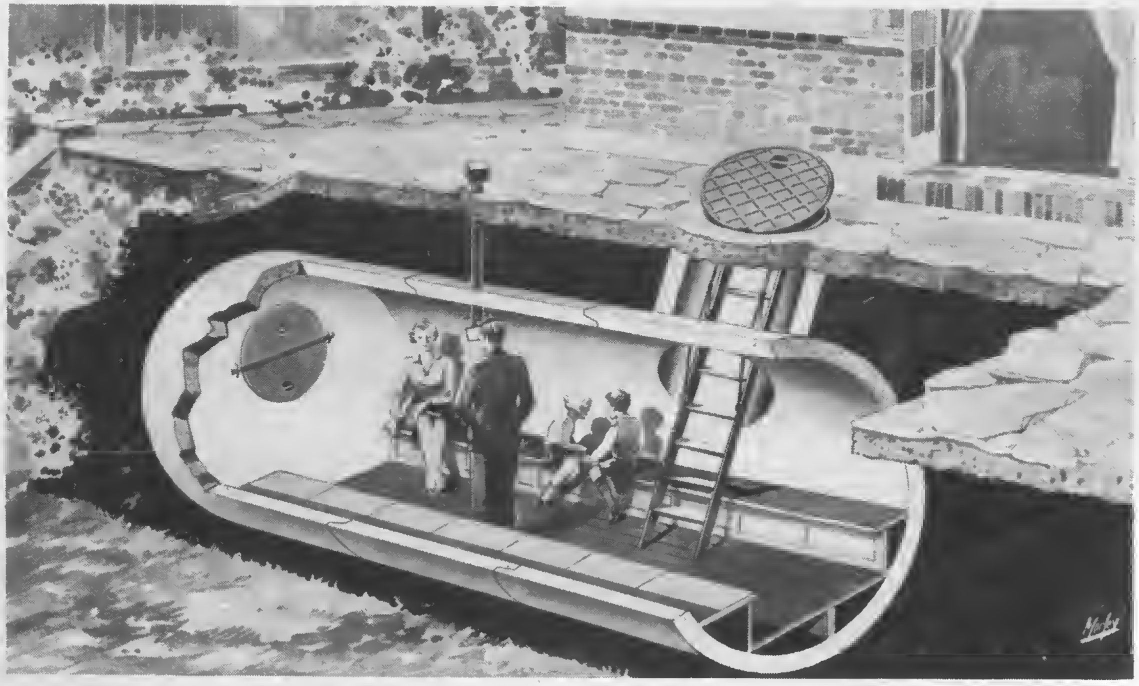
● ABOVE-GROUND TYPE

In its simplest form the very small garden splinter-proof shelter can be "home-made" with materials costing less than a five pound note. It could be a simple concrete shell 4 in. thick, covered with a mound of earth or sandbags. The concrete floor, 3 in. thick, might be a couple of feet below ground level, and the ends left open except for hanging blankets, but masked by traverses of sandbag walling. Such a shelter would not be gas-proof, but would give reasonable protection from splinters and flying debris.

A similar type of shelter, but more pretentious and giving a greater degree of protection, has been developed from the curved corrugated iron type of hut, familiar to those who took part in the 1914-18 struggle. In its air-raid shelter guise, the corrugated-iron structure is covered with a mound of earth, preferably with an 8 or 10 in. layer of concrete outside the corrugated iron sheets. These shelters may be obtained, completely equipped and gas-proofed, in family and larger sizes, delivered and erected for a net sum. The larger sizes could be adapted to serve as a garage in normal times, and the smaller variety is useful for storing tools, cycles, etc.

Another form of construction of concrete

* *See the leaflet "Concrete Storage Cellars."*



Possibly one of the easiest and most economical ways of constructing an efficient splinter-proof shelter is to use large precast concrete tubes, laid like a section of a sewer, either wholly or partly below ground. Such shelters may be purchased complete, and installed with the minimum of disturbance as little or no formwork for in situ concreting is involved.

shelters, which is equally suitable for above or below ground work, consists in using as permanent inside formwork curved interlocking steel sheets of the type sometimes employed in mine galleries.

● BELOW GROUND (wholly or partially) TYPE

If these are constructed of *in situ* concrete the problem is very similar to that of building a basement shelter. The roof must be strong enough to carry safely the weight of the superimposed earth: if Table No. 3 is followed in designing the roof slab the latter will support 550 lb. per sq. ft., or say a thickness of 5 or 6 ft. of earth, which, of course, is far more than is required for stopping splinters, etc.

If the upper parts of partly buried shelters which are to be put to a peace-time use are left uncovered temporary openings for light and ventilation may be formed, but in this case either the concrete must be thick enough to stop splinters (e.g., 12 in. of normal reinforced concrete), or earth for forming a covering, either as a mound or as sandbag work, should be kept at hand for rapid use in an emergency. For stopping

splinters, etc., either 12 in. of normal reinforced concrete or 30 in. of earth is sufficient, so 1 in. of reinforced concrete is equivalent to $2\frac{1}{2}$ in. of earth: consequently if, for example, the upper part of the shelter is composed of reinforced concrete 4 in. thick, the earth mound or covering over the concrete should be not less than $2\frac{1}{2} \times (12-4) = 20$ in. thick.

● CONCRETE TUBE SHELTERS

One of the easiest and most economical ways of constructing a splinter-proof shelter is to use sections of 72 or 78 in. diameter *precast concrete tube, laid like a section of a sewer, as shown in the illustration. The shelter may be either wholly or partially below ground. The tube may be obtained in short lengths of 2 ft. and upwards, thus permitting its introduction up narrow garden paths, etc. There are several firms prepared to instal shelters of this nature, and demonstration tube shelters may be inspected at their works and elsewhere. As formwork for concrete work is avoided, the minimum of disturbance in the garden is caused. Concrete tube shelters are popular on the continent, particularly in Germany. Table No. 4 shows the capacity of tube shelters of various sizes (see *also Table No.* 1

TABLE NO. 4

Capacities of concrete tube shelters on the basis of 75 sq. ft. of interior surface area per person, for 6 hours occupation when closed and unventilated.

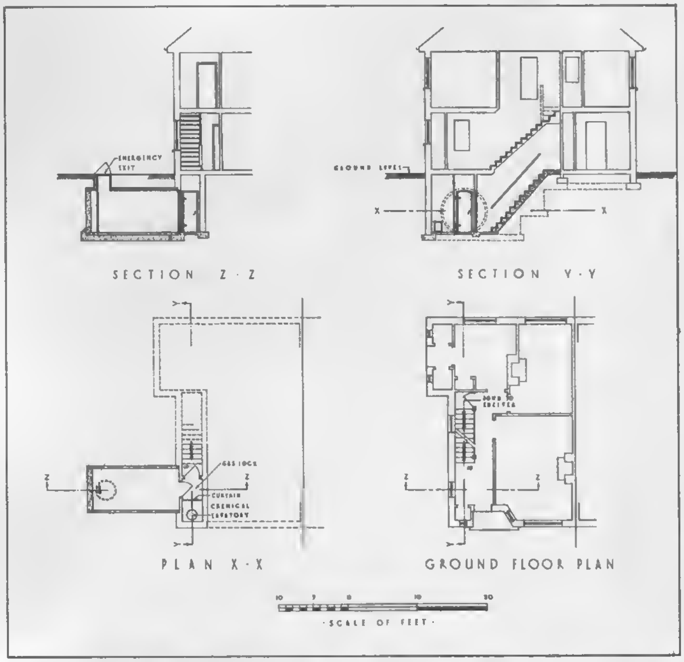
Shelter (horiz.)		Entrance (vert.)		Interior Surface Area	6 hr. cap. (person)
Length	Dia.	Length	Dia.		
8 ft.	72 in.	$8\frac{1}{2}$ ft.	27 in.	250 sq. ft.	3.3
16 ft.	72 in.	$8\frac{1}{2}$ ft.	27 in.	400 sq. ft.	5.3
8 ft.	78 in.	9 ft.	27 in.	280 sq. ft.	3.8
16 ft.	78 in.	9 ft.	27 in.	440 sq. ft.	5.9

If the shelter is ventilated comfortable capacity is at the rate of 1 person for each foot of length, seated in 2 rows vis-a-vis.

**Precast Concrete tube up to 90 in. dia. is obtainable.*

Installing a concrete tube shelter in a London back garden.

Inside a six foot diameter concrete tube shelter, suitable for a small family.

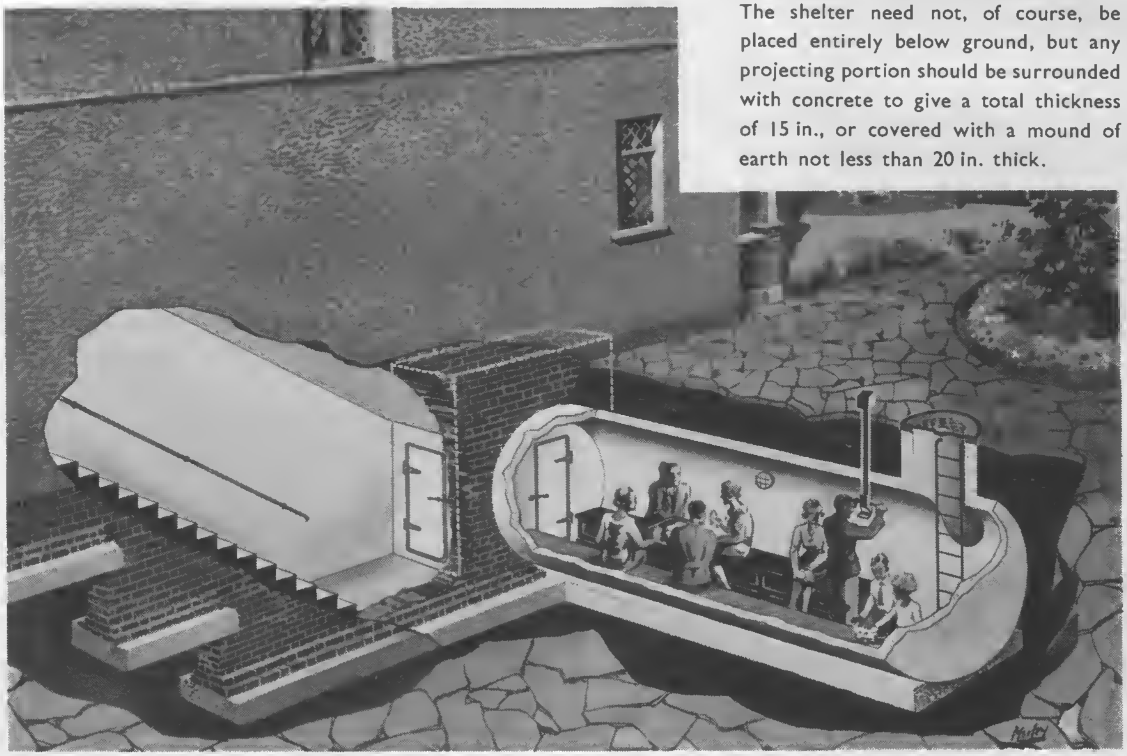


A lay-out for a concrete tube splinter and gas-proof shelter, which is recommended for incorporation in the plans of new houses, is shown in the illustration and drawings on this page.

The plans represent a typical small residence, and it will be noted that the only extra work involved is the construction of a flight of steps below the stairs to give access to the shelter from the inside of the house. The manhole type emergency exit at the outer end of the shelter is in the best position to avoid risk of blockage by debris. In normal times the shelter can be used as a cool cellar for food storage, or similar purposes.

On housing estates the concrete tube could be carried right through between adjacent houses, forming one shelter common to both, and thus avoiding duplication of equipment such as ventilation plant (if any), periscope, etc.

The shelter need not, of course, be placed entirely below ground, but any projecting portion should be surrounded with concrete to give a total thickness of 15 in., or covered with a mound of earth not less than 20 in. thick.



Ready-made shells or frameworks for splinter-proof garden shelters may be purchased in a variety of designs. The names of the makers of those illustrated on this page will be given gladly on request.

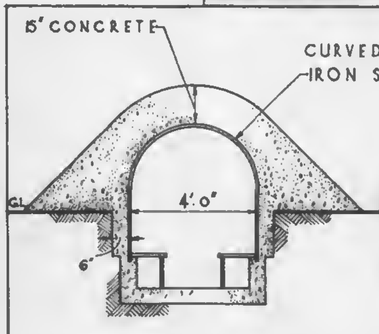
The sketches suggest ways in which the shelters may be completed by covering the shell with the necessary thickness of concrete, or concrete and earth, to give splinter-proofness.

Figs 1, 2 and 3 show a small and inexpensive curved corrugated iron shelter suitable for the garden, and alternative ways of completing it.

Fig 4 is a similar, but rather larger, structure entirely above ground. This type occupies more space, but forms a useful shed for normal use.

Fig 5 incorporates lock-sheet steel lining of the type often use in mining galleries. It is very strong, and is suitable for positions above or below ground.

Fig. 6 embodies pre cast concrete floor units, and in the size shown accommodates seven persons for six hours continuously without ventilation, or up to 16 persons with ventilation.



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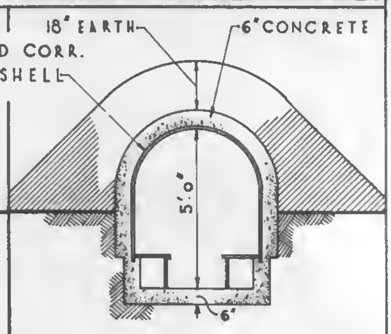

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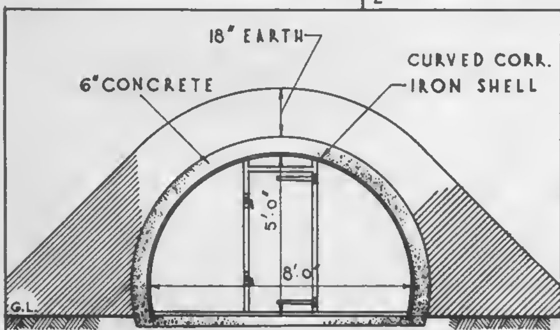

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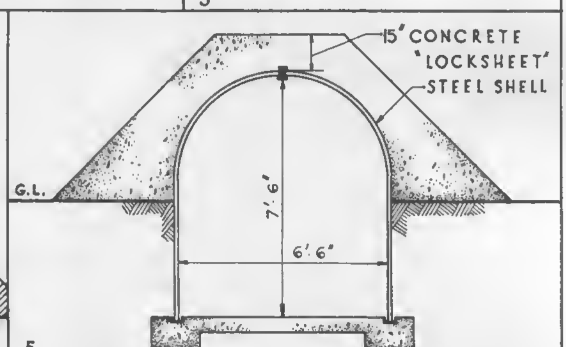

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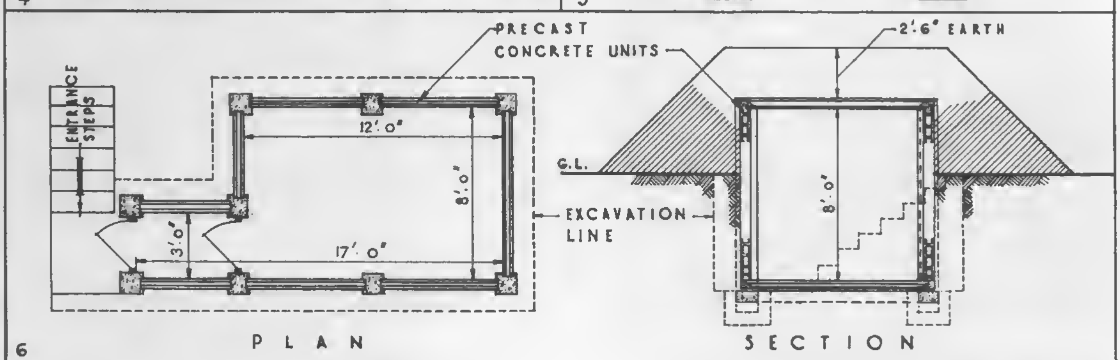


6

A SIMPLE TYPE OF GARDEN SHELTER.

NOTES :

(1) No formwork required.

(2) For convenience in handling the 78″ diameter concrete tube may be in two or more sections.

(3) The excavated material is filled into sand-bags, which are then built up over the top of the tube.

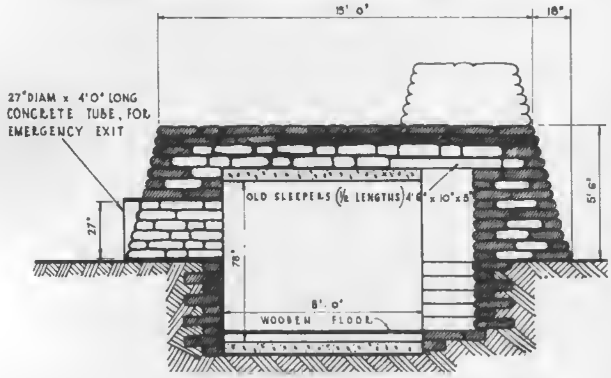
(4) For permanence and extra protection, the outer layer of sand-bags (shown shaded) contain 1 : 2½ : 4 concrete. If the site is wet, the below-ground level work may be in situ concrete instead of sand-bags

(5) If required to be gas-proof, doors or curtains may be fitted in the entrance to form a gas-lock between X.X. and Y.Y. and at Z.Z.

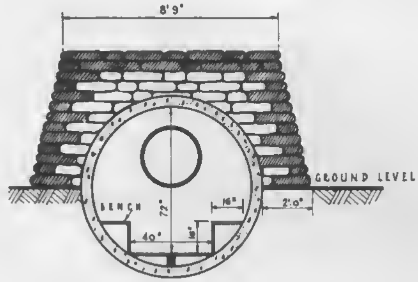
(6) If the shelter is constructed against the wall of a house, the top of the shelter can be used as a terrace, with access through French windows. The entrance to the shelter may be arranged to provide direct communication with the house. The inside may be used as a store.

(7) Rock gardens may be constructed against the sides of the shelter. The outer surfaces may be painted with cow-dung and water to induce moss growth.

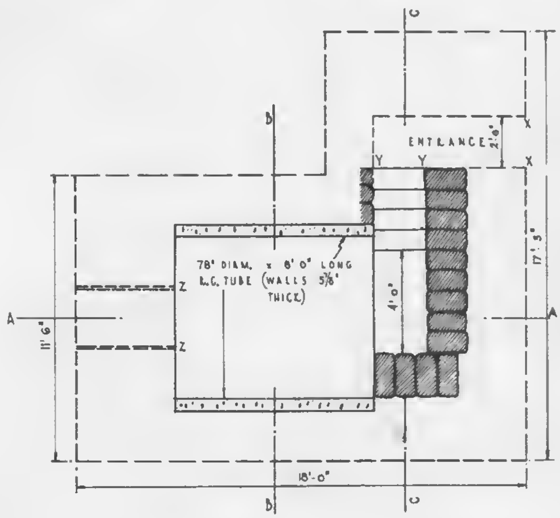
(8) Army sand-bags, when sufficiently filled and flattened, measure approximately : 20″ x 10″ x 5″. They should not, of course, be completely filled ; from two-thirds to three-quarters is sufficient. If too full, they cannot be squared-up and flattened when being laid.



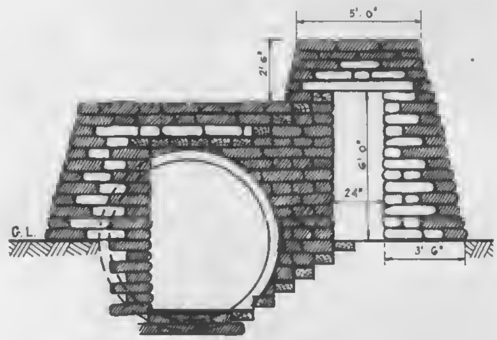
SECTION A.A.



SECTION B.B.



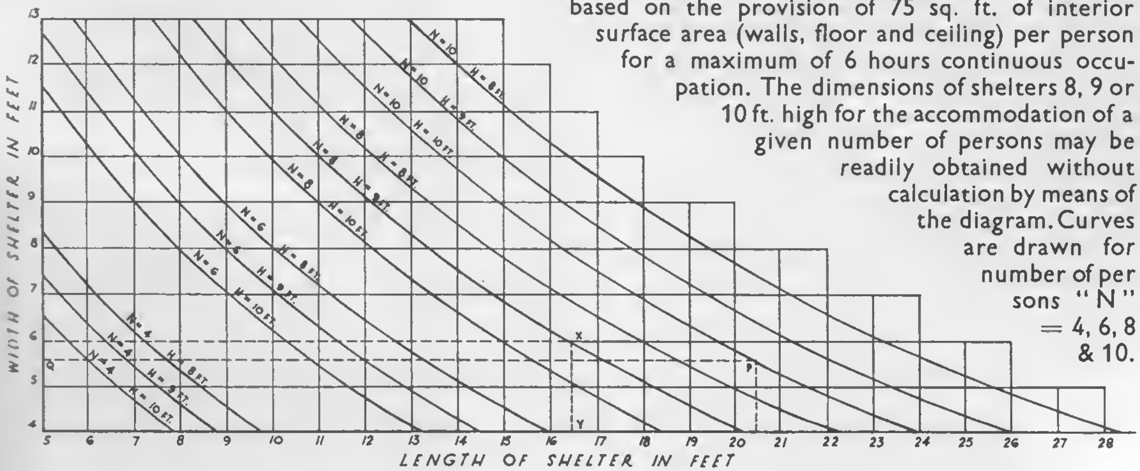
PLAN AT GROUND LEVEL



SECTION C.C.

DIMENSIONS FOR CLOSED UNVENTILATED SHELTERS for 4, 6, 8 & 10 occupants

The Home Office A.R.P. Handbook No. 6 recommends that the capacity of closed unventilated shelters be based on the provision of 75 sq. ft. of interior surface area (walls, floor and ceiling) per person for a maximum of 6 hours continuous occupation. The dimensions of shelters 8, 9 or 10 ft. high for the accommodation of a given number of persons may be readily obtained without calculation by means of the diagram. Curves are drawn for number of persons "N" = 4, 6, 8 & 10.



Examples :

- *An unventilated shelter is to accommodate 8 persons : the height inside is to be 9 ft., and the width 6 ft. What should be the length to give a total inside surface area of 75 sq. ft. per person?*
  From the figure 6 on the Width scale on the left, follow a line parallel with the Length scale as far as the point X on the H=9 ft. curve in the 8 persons series. The point Y on the Length scale, vertically below X gives the required length=16 ft. 5 in.
- *A shelter is 20 ft. 6 in. long and 10 ft. high. Find the width required for 10 occupants.*
  From the reading 20 ft. 6in. on the Length scale, follow a vertical line to the point P on the curve for H=10 and N=10. From P follow horizontally to Q and read off the width=5 ft. 7 in.

In some continental countries all new houses are required by law to incorporate gas- and splinter-proof shelters. Enterprising developers of housing estates in this country are voluntarily following suit. The house illustrated above has a small shelter below the garage, the walls, floor and ceiling being reinforced concrete 12 in. thick.

PROTECTION FROM FIRE

Concrete splinter-proof shelters as described in the preceding pages, would in themselves afford adequate protection from incendiary bombs. Every householder should, however, examine his roof and attic, and take appropriate action to minimise the risk of his house being set on fire by an incendiary bomb. In houses with pitched roofs, if the attic is kept clear of all combustible material and the floor covered with a 4 or 5 in. layer of concrete (reinforced to span if the floor is not strong enough to carry the weight) and all timber roof members treated with an efficient fire-proof mastic, the probability is that a small incendiary bomb would do no more harm than penetrate the roof and burn itself out on the attic floor. Flat roofs may be prepared in a similar manner. In the case of new buildings it is a comparatively simple matter to design for incendiary bomb protection, and the small extra cost involved is undoubtedly fully justified, especially as, according to current information, war risk fire policies are not obtainable.

CONCRETE MIXTURES FOR AIR-RAID SHELTER CONSTRUCTION

Reinforced concrete work	....	Mix D (1 : 2 : 3). Max. agg. $\frac{3}{4}$ in.
Mass concrete work	....	Mix C (1 : $2\frac{1}{2}$: 4). Max. agg. $1\frac{1}{2}$ in.

Do not use too much water: the drier the mix, provided it is workable, the better the concrete. (*See also the leaflet "Suggested Mixtures for Several Classes of Construction."*)

"The services of the Cement and Concrete Association are available on application, and free advice will gladly be given in all cases where concrete is concerned. The names and addresses of those responsible for the design and construction of shelters illustrated in this leaflet will gladly be furnished on request, where possible".

CEMENT AND CONCRETE ASSOCIATION

52 GROSVENOR GARDENS, LONDON, S.W.1

Telegrams : ADVICRETE, SOWEST, LONDON   Telephone : SLOANE 5255

Z.3.

AIR-RAID SHELTERS

LEAFLET NO. 4

(Second edition)

PUBLIC AIR-RAID SHELTERS

ISSUED BY THE

CEMENT AND CONCRETE ASSOCIATION

52 GROSVENOR GARDENS LONDON, S.W.1

AIR-RAID SHELTERS

No. 4. PUBLIC AIR-RAID SHELTERS

CONTENTS

PUBLIC AIR-RAID SHELTERS

THIS leaflet should be read in conjunction with Leaflet No. 1 (General) of this series, in which it is explained why the splinter-proof shelter is a practicable proposition and can be provided at a reasonable cost (whereas the type of shelter which would give protection from a direct hit by a heavy high-explosive bomb as a general rule cannot), and in which air-raid shelters are classified into various categories according to the purpose for which they are intended.

THE FUNCTION OF PUBLIC SHELTERS

IT is highly desirable that shelters should be designed to serve a dual purpose, for if they can perform some useful function in normal times their cost from the point of view of A.R.P. is correspondingly reduced. Pedestrian subways under busy streets at once suggest themselves. Basement shelters need not preclude the basement being used for its ordinary purpose of storage space or office accommodation, if a plan is drawn up for the rapid removal of the contents in an emergency. Shelters in open spaces such as parks, city squares, and so forth need not spoil the amenities, for if constructed of reinforced concrete they could be placed below the surface without risk of deterioration, and would serve as store depots, etc. Car-parks which would help to relieve traffic congestion, could be constructed beneath public squares: they would produce a revenue from parking charges, and it would be feasible in an emergency for the parks to be divided by temporary splinter-proof walls into compartments to accommodate the desirable maximum of 50 persons in each. Even trenches, if revetted with concrete, could be laid out in parks as an ornamental feature and filled with water: or they could be covered with precast concrete slabs to form formal paths, the space beneath being used for the storage of gardeners' tools and as depots for park material.

The following extracts from the memorandum on air-raid precautions addressed by the Home Office to local authorities make clear the purpose for which public shelters are intended:

" It is one of the duties of local authorities to provide such shelters for the protection of the public as may be necessary . . . the wisest policy is to aim at the dispersal of the population. Generally speaking, therefore, persons who, at the time of an air-raid, are either in their own homes or in other buildings should remain there . . . it must be assumed that householders will generally do what they can to increase the natural protection of their own homes, and that employers . . . will have made arrangements for such protection and shelter in their business premises as may be practicable. It is possible, however, that in some areas the houses or premises . . . are such that adaptation to provide protection to any reasonable degree is impracticable. In addition there may be in the streets considerable numbers of people . . . ."

It is quite clear from the above that the onus of providing shelters rests primarily on the householder and the employer, and local authorities are not expected to provide public shelters for the use of everyone, but only for (1) people caught in the streets and unable to reach their homes or places of employment within 10 minutes in order to take refuge in their scheduled shelter, and (2) for the protection of the people in certain areas where the nature of the buildings is such that it is impossible for the occupants to improvise their own home shelters. As regards the latter, a decision on whether or not public shelters are required for some of the residents will have to be taken in due course, presumably after the provision of home shelters by the majority has shown how far similar action by the remainder would be feasible.

NUMBER AND DISTRIBUTION OF PUBLIC SHELTERS

IT would seem, therefore, that the first steps to be taken by local authorities are:—

❶ Obtain the police estimate of the maximum number of people likely to be in the streets, and then to mark on a large scale street plan the desirable distribution of shelters for their accommodation, bearing in mind that the shelters should be so located that they can absorb the street population in under ten minutes, and that as far as possible no single splinter-proof shelter should accommodate more than 50 persons.

❷ Make a survey of all available basements capable of adaptation for shelters, and determine what proportion of the floating population of the streets could be accommodated in those basements (if any) not required by the occupants of the buildings above.

❸ Consider how best to provide shelters for the remainder.

SPLINTER-PROOF OR BOMB-PROOF?

ALTHOUGH the high-explosive bomb is admittedly the greatest danger, it is not so much the direct hit that has to be anticipated as the other effects of these bombs such as splinters, blast and falling debris. Generally speaking, owing to the great cost of 100 per cent bomb-proof shelters, the majority of public shelters are likely to be splinter- and gas-proof, giving a reasonable degree of protection from all hazards except the remote chance of a direct hit by a high-explosive bomb. It should be realized that the chances of the latter occurring are extremely small, for it can be shown that even if all the 8½ million London inhabitants living within 15 miles of Charing Cross were to be distributed in shelters providing 7½ sq. ft. of floor space per person, and evenly disposed throughout the 700 odd square miles, less than one-three hundredth of the area would be covered with shelters. This means that more than 300 bombs would have to be dropped for every one direct hit scored on a shelter. It may be remarked in passing that, as the elementary strategy of dispersal of target applies to defence against attack from the air, it is obvious that the smaller the size of each shelter, and consequently the greater the number of them, the fewer the casualties from a given number of bombs dropped.

Although it is evident that a very high degree of protection for the population as a whole may be obtained by the provision of splinter-proof shelters, the possibility of constructing bomb-proof (as distinct from the gas- and splinter-proof) public shelters in certain cases should not, of course, be disregarded by local authorities. Where there

exists some conveniently situated natural feature, such as a cavern in a suitable hill, or some artificial structure such as a tunnel or mine gallery, etc., it might be found feasible to take advantage of it and to provide therein at reasonable cost a shelter giving absolute security from all hazards. An example of this is the case of the Paris underground railway, certain sections of which have been assigned and are being equipped to serve as large capacity public refuges. Whether use will be made of the London tube railways remains to be seen, but it would seem that parts of the system could be turned to account and adapted on the Paris plan. Work of this nature involves a careful investigation of any steps that may be required to prevent risk of flooding, the provision of adequate and gas-proof entrances, and the installation of ventilating and gas filtration plants.

CAPACITY OF SHELTERS

LOCAL authorities will be familiar with the methods of computing the capacity of shelters, as given in the Home Office A.R.P. Department's Handbook No. 6. Table No. 1 shows at a glance how to arrive at the space required for a given number of persons according to whether the shelter is to be ventilated, or is to be used as a closed unventilated chamber. In the former case,

TABLE No. 1

TYPE OF SHELTER	SPACE REQUIRED PER PERSON
Ventilated* Example : For 50 persons at 7½ sq. ft. of floor space each—a chamber 10 ft. wide x 37 ft. 6 in. long, or 15 ft. x 25 ft., etc., by any convenient height.	Minimum for standing room only, 3½ sq. ft. of floor per person. Desirable space for reasonable comfort is not less than 6 sq. ft. per person.
Unventilated Example : For 50 persons at 75 sq. ft. surface area each—a chamber 10 ft. wide and 94 ft. long x 9 ft. high, or 15 ft. x 69 ft. x 10 ft. high ; etc.	75 sq. ft. interior surface area (walls, floor and ceiling) per person, for maximum period of occupation of 6 hours. For 12 hours occupation allow 100 sq. ft. surface area per person.

** The ventilation system should be capable of delivering a minimum of 150 cu. ft. of filtered fresh air per person per hour.*

mechanical ventilation and gas filtration plants should be capable of delivering 150 cu. ft. of air per person per hour.

The limiting factor in the capacity of unventilated shelters is not so much the using up of the oxygen supply as the gradual rise in temperature and the increase in the humidity of the air due to the presence of the occupants. The higher the temperature the more moisture the air will hold: consequently, in the absence of ventilation, it is essential to make the air give up excess moisture by inducing condensation on the inside surface of the shelter, and the extent to which this will occur depends on the temperature of the walls, floor and ceiling. The latter should be smooth, dense and inherently cold, characteristics which are readily obtainable by constructing the shelter of concrete.

Reinforced concrete, which combines strength with permanence, is the ideal material for air-raid shelter construction. The photographs show a British shelter under construction which is designed for normal use as a cycle store. Openings below the roof slab admit light and air, but in the event of war these would be closed and a mound of earth formed over the top. Public shelters of this type could be constructed under suitable side streets, the roof slab forming the road surface in normal times. A reinforced concrete slab 12 in. thick would be splinter-proof, so an earth mound for further protection would not be essential.

PROTECTION FROM SPLINTERS, ETC.

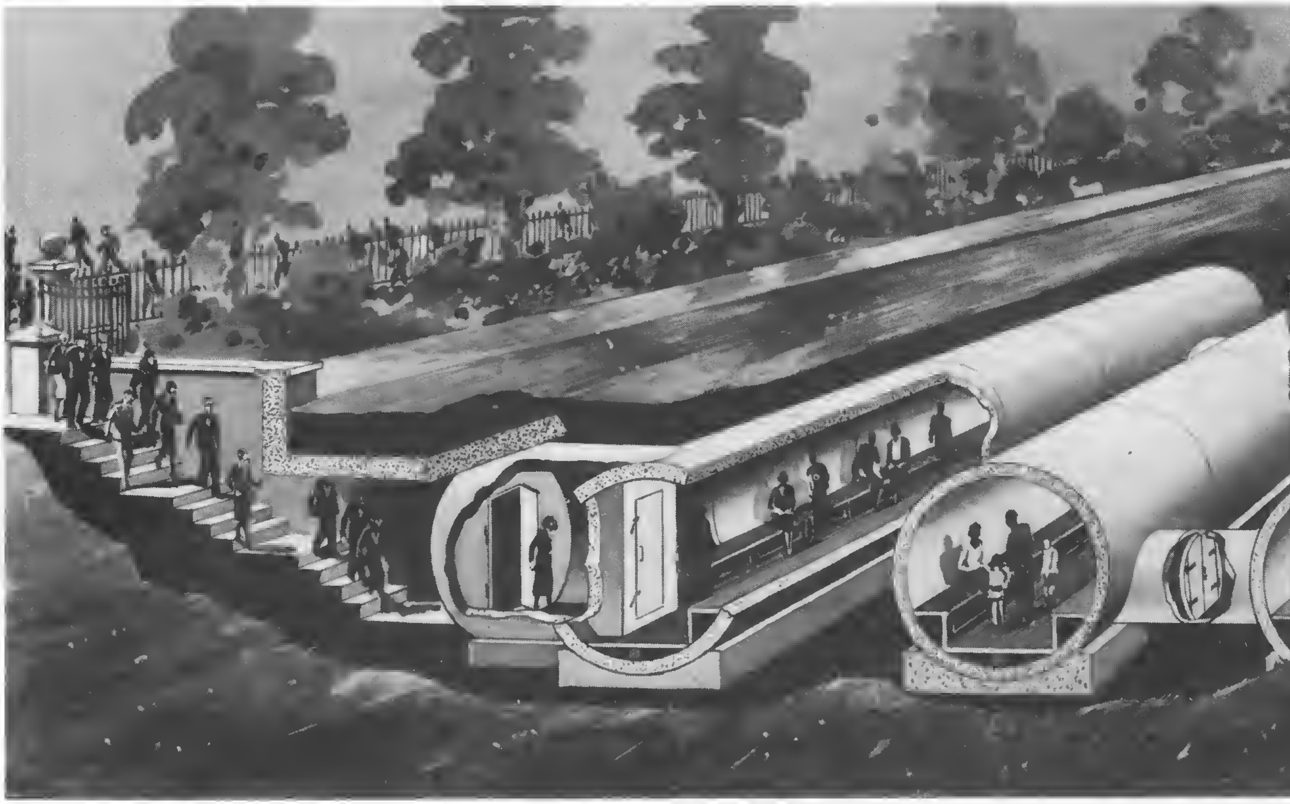
TO resist blast, and the penetration of splinters from high-explosive bombs exploding more than 50 ft. away, the following thicknesses are among those recommended by the Home Office in A.R.P. Handbook No. 6 (*obtainable from H.M. Stationery Office, price 6d.*):—

TABLE No. 2		
Reinforced concrete 5 in. thick may be expected to keep out incendiary bombs* of 1 kilo weight (2¼ lb.)	Earth or Sand	30 in.
	Unreinforced concrete (not weaker than 1 : 6) ...	15 in.
	Stock bricks in cement mortar	13½ in.
	Reinforced concrete (normal)	12 in.
	Reinforced concrete (special)	10 in.
	Mild steel plate	1½ in.

** R.C. 15 in. thick affords protection from 10 kilo (23 lb.) incendiary bombs.*

STRENGTH OF SHELTER ROOF

THE roof of a shelter in, under, or adjoining a building must be strong enough not to collapse if the building above should fall upon it. The economic strength for the roof of such a shelter to give protection from falling debris naturally depends on the nature of the building and the number of stories above. Experience in Spain has shown that a building having solid load-bearing walls is much more likely to be demolished by blast or a direct hit by an H.E. bomb, than a reinforced concrete framed building: the latter stands up, even if part of the framework is damaged, and the weight of the debris, composed of light panel walling, floor material, etc., is much less than that arising from the collapse of a solid type of building. It is obvious, therefore, that to support the weight of debris which might fall on it the immediate roof over shelter accommodation, or what may be termed the 'demolition floor' of a building, need not be so strong in a framed building as in a structure having solid load-bearing walls. The Home Office recommend that for framed buildings the debris load should be taken as 200 lb. per sq. ft., irrespective of the number of floors above; but for unframed buildings, i.e., those with load-bearing walls, the suggested debris loads in lb. per sq. ft. are 200 for 2 floors over, 300 for 3 or 4 floors over, and 400 for more than 4 floors over. These figures, which incidentally are the same as the German recommendations, are in addition to the normal live load, and in designing 'demolition floors' it should not be forgotten to add the latter. In Table No. 3, which is published by permission of Mr. L. Scott White, M.Inst.C.E., M.I.Struct.E., similar reinforcement is provided in both directions for the purpose of distributing the effects of heavy local loads due to falling masonry, etc. Steel fabric reinforcement of equivalent value may, of course, be used instead of M.S. rods, if desired. Some form of permanent shuttering on the underside of 'demolition floors' will prevent risk of the soffit spalling under impact of falling debris, etc.

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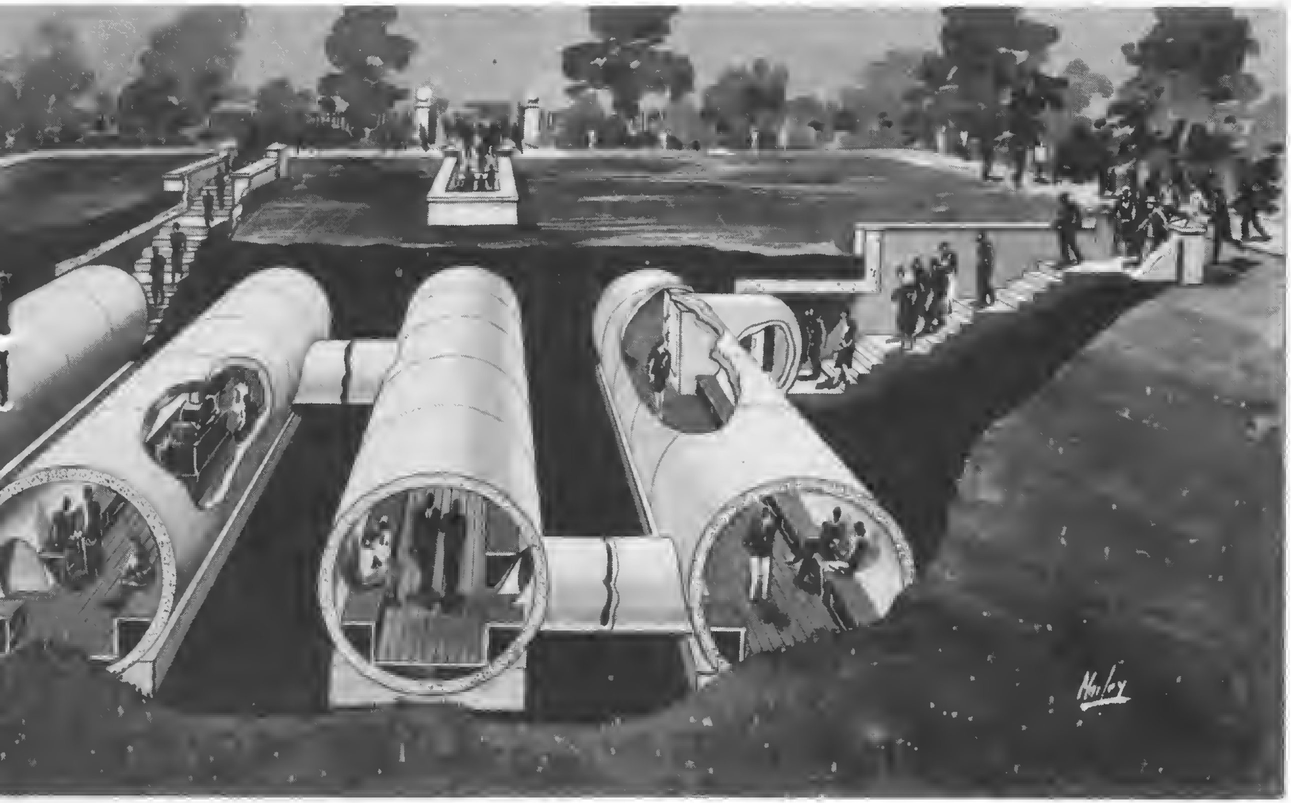


One of the most convenient and economical ways of constructing a public splinter-proof shelter is to use large diameter precast concrete tubes, laid like a section of a sewer partly above ground and with a mound of earth over the top. If equipped with a ventilating and gas-filtration plant a tube 72 in. or 78 in. diameter by about 50 ft. long would accommodate 50 persons. Precast concrete tubes up to 90 in. diameter are obtainable.

Multiple concrete tube shelters could be installed under city squares without spoiling the amenities. Each unit would accommodate 50 persons, and would have its own entrance. The whole group could be interconnected and ventilated by a central gas-filtration plant. Gas-proof doors in the connecting tubes would prevent the immobilisation of the rest of the system if any of the units should sustain damage. The main tubes would naturally be spaced as far apart as space permits for the accommodation of the scheduled number of persons.

TABLE NO. 3

R.C. SLAB "DEMOLITION FLOORS" OR ROOFS OF SHELTERS WITHIN BUILDINGS.

(1) *The design load includes the normal live load plus the 'demolition load,' and is in addition to the weight of the slab.*

(2) *The reinforcement is M.S. rods (Max. tension 18,000 lb. per sq. in.) placed in the bottom of the slab, with 1 in. cover, and is spaced at 6 in. centres in both directions, forming a grid. Steel fabric reinforcement of equivalent value may be substituted, if desired.*

(3) *Proportions of concrete of ordinary grade : 1 : 2½ : 4. Max. compression in concrete 750 lb. per sq. in.*

(4) *Slabs free-ended. Modular Ratio 15. Bending Moment B=WL÷8.*

DESIGN LOAD lb. per Sq. ft.	6 ft. Span		B ft. Span		10 ft. Span		12 ft. Span		16 ft. Span		20 ft. Span	
	Inches Thick	Inches Dia. M.S. Rods	Inches Thick	Inches Dia. M.S. Rods	Inches Thick	Inches Dia. M.S. Rods	Inches Thick	Inches Dia. M.S. Rods	Inches Thick	Inches Dia. M.S. Rods	Inches Thick	Inches Dia. M.S. Rods
250	5	½	6	⅝	7	⅝	9	¾	12	⅞	15	1
280	5	½	7	⅝	8	⅝	9	¾	12	⅞	15	1
300	5	½	7	⅝	8	⅝	9	¾	13	⅞	16	1
350	6	½	7	⅝	9	¾	10	¾	13	⅞	17	1
380	6	½	7	⅝	9	¾	10	¾	14	⅞	17	1
400	6	½	7	⅝	9	¾	10	¾	14	⅞	18	1
450	6	½	8	⅝	9	¾	11	¾	14	1	18	1
480	6	⅝	8	⅝	10	¾	11	¾	15	1	19	1
500	6	⅝	8	⅝	10	¾	11	⅞	15	1	19	1⅛
550*	6	⅝	8	⅝	10	¾	12	⅞	16	1	20	1⅛
600	7	⅝	9	¾	10	¾	12	⅞	16	1	20	1⅛
											(L. Scott White)	

* *A rule of thumb apparent for this loading is that one inch of thickness of R.C. is required for each foot width of the shelter.*

TYPES OF SPLINTER-PROOF SHELTERS

ALL public shelters should be provided with an air-lock at the entrance, emergency exits and lavatory accommodation. The general principles of lay-out and equipment of shelters are given in the Home Office A.R.P. Department's handbooks, and need not be dilated upon in this leaflet.

❶ BASEMENT SHELTERS

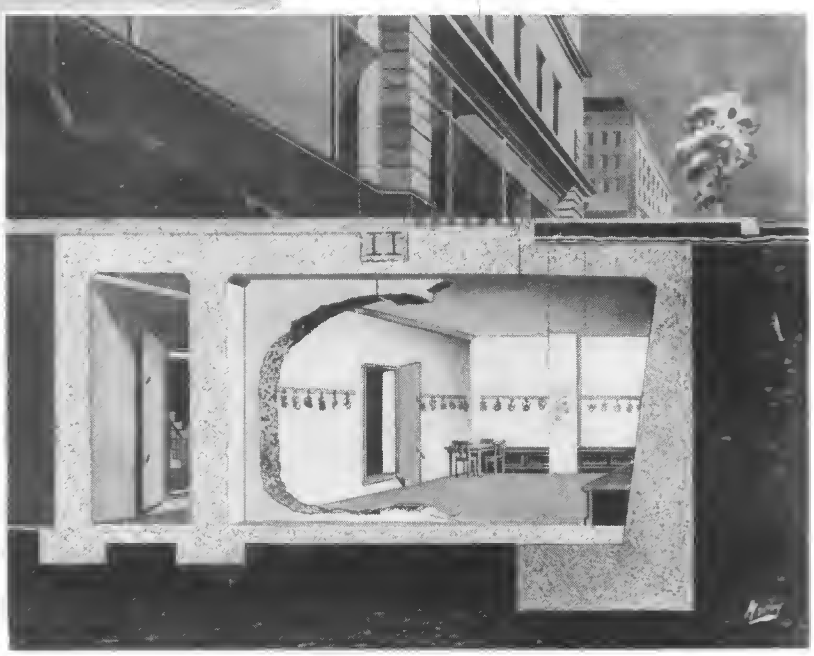
Below ground level is obviously the best place for a shelter because of the lateral protection thus secured. If in addition the shelter is located beneath a building it will derive a measure of protection from direct hits by high-explosive bombs repre-

sented by the additional overhead cover given by the roof and floors of the buildings above. Basement shelter roofs have to be strong enough to withstand safely the collapse of the building above them.* Points to be observed in the design of basement shelters, or in the adaptation of existing basements are discussed at length in Leaflet No. 2 of this series (*copies of which may be obtained free on request*).

❷ TRENCHES

Military tactics are applicable to passive resistance to attack from the air, and where open spaces well clear of buildings are available on the property a considerable measure of protection may be provided by a system of trenches. Full instructions for the design and construction of trenches are given in the Home Office's A.R.P. Handbook No. 6, so details need not be entered into in this leaflet. It

Inside a fully equipped London basement shelter constructed of reinforced concrete.



Adaptation of typical basement by strengthening ceiling and constructing concrete partition walls between existing columns. Where possible an underground passage leading to an emergency exit well clear of the building should be provided.

** Notes on the strutting of floors have been prepared by the A.R.P. Dept. of the Home Office, and advice on the subject may be sought from that source.*

should be remembered, however, that if reliance is to be placed in trenches they should be constructed in such a manner that they will be permanent. For this purpose "A" frames and revetting material should be of concrete, which will not deteriorate with the passage of time.

Trenches may be provided with overhead cover to give protection from falling bomb splinters, fragments of anti-aircraft shells and debris, in which case they become a form of dugout or splinter-proof shelter. If precast concrete slabs are used for the overhead cover, resting on the top of concrete revetment, and recessed so as to be flush with the surface of the ground, the trench system may be laid out as a formal zig-zag path. Another means of obviating unsightliness is to construct the trench in concrete and fill it with water, so designing it that it forms an ornamental fish or lily pond in normal times. In war time additional overhead cover in the form of sandbags or an earth mound may be quickly placed on top of the slabs, if the necessary material is kept at hand.

Another method of securing permanence is to revet the trenches with sandbags containing wet concrete instead of earth or sand: permanent breastworks may be constructed in the same manner. The bags should be only a little over half full, otherwise it is difficult to 'square' them up neatly when laying so as to secure a good bond.

❸ SHELTERS IN OPEN SPACES (ABOVE GROUND)

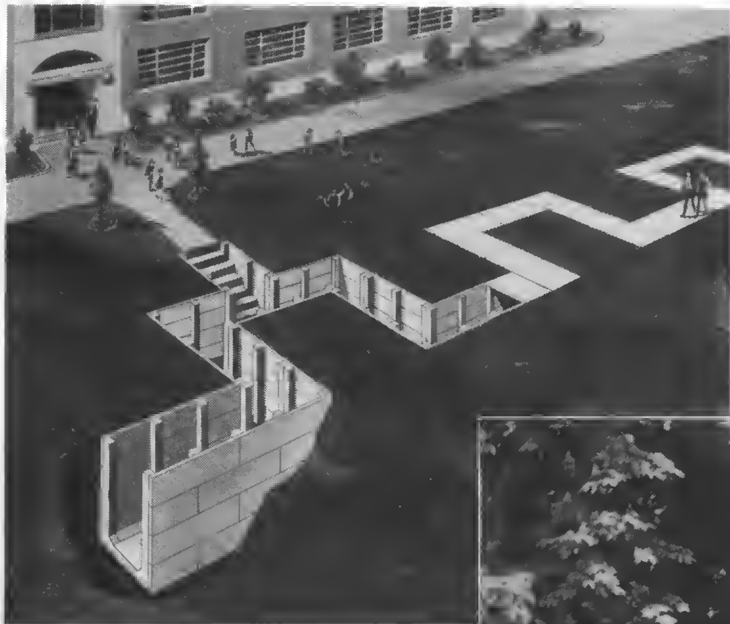
The design and construction of splinter-proof shelters in the open is clearly a much simpler problem than that involved in the design of shelters under buildings, for the main structural requirement is merely the incorporation of a sufficient thickness of material to prevent penetration by splinters of high-explosive bombs, and to give protection from direct hits by small gas and incendiary bombs, falling debris, etc., as shown in Table No. 2. Bearing in mind the questions of accessibility, capacity and gas-proofing the problem resolves itself into what shape and form of construction is the most suitable to the site, and is possible with the money available, and, further, to design the shelter so that in normal times it may be put to the best use.

An alternative to the straightforward above-ground reinforced concrete splinter-proof structure of the lean-to or isolated 'pillbox' type, is the curved corrugated iron hut, familiar to those who took part in the 1914-18 world war, with an 8 or 10 in. layer of concrete outside the corrugated iron sheets, and covered with a mound of turfed earth. A concrete floor is an advantage in any case, but is particularly desirable if the shelter floor is to be sunk a foot or two. These shelters are simple to construct, and the component parts, including gas-proof doors, etc., are on the market. They are particularly suitable for placing among trees in public squares, and in parks near adjacent streets.

A variation is to use for permanent inside form-work curved interlocking steel sheets of the type sometimes employed in mine galleries, and which are readily obtainable commercially. This form of construction is, of course, equally suited to above or below ground work.

❹ SHELTERS IN OPEN SPACES (BELOW GROUND)

If these are constructed of *in situ* concrete the problem is very similar to that of building a basement shelter. The roof must be strong enough to



Trenches provide a considerable measure of protection, but if they are to be relied upon they should be revetted with an imperishable material, such as concrete, which entails no expenditure on maintenance. If precast concrete slabs are used to cover the trenches they may be covered with earth or sandbags for extra protection in an emergency.

The curved corrugated iron type of hut, which proved so useful in 1914-18, makes an excellent splinter-proof shelter if covered with 8 or 10 in. of concrete and a mound of earth, and is particularly suitable for erection in such open spaces as parks, where there would be no objection to the considerable mounds of earth involved.

carry safely the weight of the superimposed earth: Table No. 3 will be useful in this connection. Shelters near buildings and within range of falling debris should have roofs designed to carry the 'demolition load' in addition to the weight of covering earth.

If the upper parts of partly buried shelters which are to be put to a peace-time use are left uncovered temporary openings for light and ventilation may be formed, but in this case either the concrete must be thick enough to stop splinters (e.g. 12 in. of normal reinforced concrete), or earth for forming a covering, either as a mound or as sandbag work, should be kept at hand for rapid use in an emergency. For stopping splinters, etc., either 12 in. of normal reinforced concrete, or 30 in. of earth, is sufficient, so 1 in. of reinforced concrete is equivalent to $2\frac{1}{2}$ in. of earth: consequently, if, for example, the upper part of the shelter is composed of reinforced concrete 4 in. thick, the earth mound or covering over the concrete should be not less than $2\frac{1}{2} \times (12-4) = 20$ in. thick.

One of the easiest and most economical ways of

constructing a splinter-proof shelter is to use sections of large diameter precast concrete tube, laid like a section of a sewer, either wholly or partly below ground. The circular section is inherently strong, but if, in addition, the tube is bedded on and haunched with *in situ* concrete strength to withstand enormous external pressures may be readily attained, and this procedure is recommended for tube shelters below buildings, and in other deep level situations where a degree of protection from direct hits by high-explosive bombs is to be looked for. The tube may be obtained from leading manufacturers of concrete pipes in short lengths of 2 ft. and upwards, thus permitting its easy handling and introduction through narrow spaces. Demonstration concrete tube shelters of various capacities, and in diameters from 72 in. to 90 In., may be inspected at the works of certain manufacturers, and elsewhere (*addresses will be furnished on request*). A shelter, equipped with a ventilation and gas-filtration plant to seat 50 persons in comfort would be about 50 ft. long. Such shelters, completely equipped, may be obtained and installed at a cost which compares favourably with any other type of shelter giving the same degree of protection.

Concrete tube shelters are popular on the Continent, particularly in Germany. They may be installed in parallel groups, each unit holding 50 persons, and being inter-connected to the next unit by a smaller diameter tube, the whole series being ventilated by a central gas-filtration plant. The possibilities of concrete tube public splinter-proof shelters on this plan, laid below the surface in

Inside a 90 in. diameter splinter-proof concrete tube shelter in the Midlands, accommodating 50 persons. Laid like a section of a sewer these shelters are inexpensive, easy to construct, and cost nothing for maintenance.

An underground car-park constructed to serve as a public air-raid shelter represents the provision of two essential public services at little more than the cost of one. In an emergency the park could be divided by temporary splinter-proof walling into cells accommodating the desirable maximum of 50 persons in each.

parks, squares, school playgrounds and other open spaces reasonably free from service mains and sewers, should receive careful consideration by local authorities. The work involved is very similar to the laying of precast concrete sewers in open cut, and in the light of previous departmental experience is therefore simple to estimate the cost of and to carry out.

⑤ UNDERGROUND CAR-PARKS AS SHELTERS

The problem of relieving traffic congestion in urban districts is one which faces the majority of, if not all local authorities, and it is generally conceded that the provision of more and better car-parking facilities is highly desirable. Public car-parks beneath city squares and other suitable open spaces would not compete with private enterprises any more than surface car-parks: for petrol, service, and so forth the motorist would depend on the ordinary filling station or garage, and, therefore, the latter would benefit rather than otherwise from the provision of more car-parks.

The local authority has to consider whether a public underground car-park would be a drag on the rates. Schemes have been worked out in detail which show that this need not be so; but in any case if the car-park can be designed to serve in addition as a public splinter-proof air-raid shelter, it is clear that herein lies an opportunity for the local authority to provide two essential public services for little more than the cost of one.

An objection to establishing a public shelter in an underground car-park which has been advanced is that a large number of people would be gathered together in one place: but if the park can be split up by splinter-proof walls into cells, each accommodating 50 persons, the objection would appear to lose weight. Temporary sandbag or other walling can be erected in an emergency in order to divide the park up into cells.

Arrangements for ventilation and gas-proofing present no difficulty, but as regards the roof the alternatives appear to be either one of substantial reinforced concrete* to give protection from direct hits of all but heavy high-explosive bombs, or one of splinter-proof construction designed to 'blow-off' above a direct hit detonating inside the structure, and thus localising the effect.

● MISCELLANEOUS ADAPTATIONS

Local authorities will doubtless explore the possibilities of establishing public shelters in such locations as railway arches, areas, disused sewers and tunnels, mine galleries, pits, quarries, dry water courses, caves, hillsides, slag heaps, and so forth. If each case is considered on its merits, it is possible that in some instances, it will be found that adequate shelters could be formed economically in this or that feature by the use of reinforced concrete in the work of adaptation.

* *e.g.: A 'burster layer' of heavily reinforced concrete 2 ft. 6 in. thick, with a 3 ft. layer of sand immediately below, and another layer of R.C. 3 ft. thick below the sand.*

CONCRETE MIXTURES FOR AIR-RAID SHELTER CONSTRUCTION

Reinforced concrete work	Mix D (1 : 2 : 3). Max. agg. $\frac{3}{4}$ in.
Mass concrete work	Mix C (1 : $2\frac{1}{2}$: 4). Max. agg. $1\frac{1}{2}$ in.

Do not use too much water: the drier the mix, provided it is workable, the better the concrete. (*See also the leaflet "Suggested Mixtures for Several Classes of Construction."*)

" The services of the Cement and Concrete Association are available on application, and free advice will gladly be given in all cases where concrete is concerned. The names and addresses of those responsible for the design and construction of shelters illustrated in this leaflet will gladly be furnished on request, where possible".

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